Human Exploration Strategy

Paul Niles
NASA Johnson Space Center
Jacob Bleacher
HEOMD Chief Exploration Scientist

MEPAG Meeting
26 July, 2019
Space Policy Directive 1: To the Moon, then Mars

“Lead an innovative and sustainable program of exploration with commercial and international partners to enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities. Beginning with missions beyond low-Earth orbit, the United States will lead the return of humans to the Moon for long-term exploration and utilization, followed by human missions to Mars and other destinations…”
Sustainability at the Moon and on to Mars

- The U.S. leading in exploration and setting the standards for the Moon
- Unbound potential for partnerships and collaboration
- Meaningful, long-duration human missions
- Testing impacts on human performance and exploration operations to be used for Mars
- Repeatable operations traveling from Earth to the Gateway to the surface with reusable systems
- Unprecedented science outside of Earth’s influence
- Maintains strategic presence as a deep space port and refueling depot around the Moon
- Increases international and commercial partnership opportunities, fostering healthy competition
The Artemis Program

Artemis is the twin sister of Apollo and goddess of the Moon in Greek mythology. Now, she personifies our path to the Moon as the name of NASA’s program to return astronauts to the lunar surface by 2024.

When they land, Artemis astronauts will step foot where no human has ever been before: the Moon’s South Pole.

With the horizon goal of sending humans to Mars, Artemis begins the next era of exploration.
Phase 1 & Phase 2 Definitions

Phase 1: Today – 2024
Human surface landing
Missions and systems required to achieve landing humans on the surface of the Moon in 2024

Phase 2: 2028
Establish a sustainable long-term presence on and around the Moon
Artemis Phase 1: To the Lunar Surface by 2024

**Artemis 1:** First human spacecraft to the Moon in the 21st century

**Artemis 2:** First humans to orbit the Moon in the 21st century

**Artemis Support Mission:** First high power Solar Electric Propulsion (SEP) system

**Artemis Support Mission:** First pressurized module delivered to Gateway

**Artemis Support Mission(s):** Human Lander System delivered to Gateway

**Artemis 3:** Crewed mission to Gateway and lunar surface

---

**Commercial Lunar Payload Services**
- CLPS delivered science and technology payloads

**Early South Pole Mission(s):**
- First robotic landing on eventual human lunar return and ISRU site
- First ground truth of polar crater volatiles

**Large-Scale Cargo Lander**
- Increased capabilities for science and technology payloads

**Humans on the Moon - 21st Century**
First crew leverages infrastructure left behind by previous missions

---

LUNAR SOUTH POLE TARGET SITE

2019

---

2024
Current Thoughts on Human Landing System

HLS Notional Transportation Elements

Transfer + Ascent + Descent = Aggregate at Gateway
2024

DEVELOPMENT IS UNDERWAY

- **Crew**: Develop essential hardware and systems required for a 2024 landing
  - **Suits**: At least 2 on the South Pole
  - **Expedition Duration**: Hours-Days (open trade)
  - **Rockets**: Initial capability suit (examples)
  - **Partners**: Significant collaboration with U.S. industry
  - **Access**: Potential opportunities for international partners
  - **Reusability**: Desired, but not required

2028

- **Crew**: Establish a sustainable human lunar presence with robust, reusable systems
  - **Suits**: Up to 4 on the Moon
  - **Expedition Duration**: Days-Weeks (open trade)
  - **Rockets**: Sustained capability suit (examples)
  - **Partners**: U.S. industry and international collaboration
  - **Access**: Increased mobility from the pole; global access through robotic landings and possible human expeditions
  - **Reusability**: Enables sustainability
Gateway is Essential for 2024 Landing

- Initial Gateway focuses on the minimum systems required to support a 2024 human lunar landing while also supporting Phase 2

- Provides command center and aggregation point for 2024 human landing

- Establishes strategic presence around the Moon – US in the leadership role

- Creates resilience and robustness in the lunar architecture

- Open architecture and interoperability standards provides building blocks for partnerships and future expansion
Summary of Maxar’s PPE approach

Leverage heritage reliability, proven development approach, and the scalable 1300-class platform as the basis for a PPE demonstration mission culminating with delivery of PPE to NASA in the target NRHO

- **Power** – 60 kW+ provided by Roll Out Solar Array (ROSA) and Maxar’s 1300 commercial power subsystem
- **Propulsion** – Leverage NASA development of 12.5 kW Electric Propulsion (EP), and internal Maxar advanced EP development, with Maxar expertise in system accommodation of EP elements
- **Communications** – Ka-band relay from Lunar vicinity to Earth, accommodations for future optical communications payloads
- **Guidance Navigation and Control** – Utilize proven approaches for station keeping, momentum management, and autonomous low thrust electric orbit transfer
- **Gateway Interfaces** – Support all interfaces with elements of Gateway including docked components, visiting vehicles, robotics, science payloads, Orion, and Human Landing System elements
- **Payload Transfer** – 1000kg for lunar lander or science instruments
GATEWAY ORBIT

Cislunar space offers innumerable orbits for consideration, each with merit for a variety of operations. The Gateway will support missions to the lunar surface and serve as a staging area for exploration farther into the solar system, including Mars.

ORBIT TYPES

**LOW LUNAR ORBITS**  
Circular or elliptical orbits close to the surface. Excellent for remote sensing, difficult to maintain in gravity well.  
* Orbit period: 2 hours

**DISTANT RETROGRADE ORBITS**  
Very large, circular, stable orbits. Easy to reach from Earth, but far from lunar surface.  
* Orbit period: 2 weeks

**HALO ORBITS**  
Fuel-efficient orbits revolving around Earth-Moon neutral-gravity points.  
* Orbit period: 1-2 weeks

NEAR-RECTILINEAR HALO ORBIT (NRHO)

1,500 km at its closest to the lunar surface, 70,000 km at its farthest.

**ACCESS**  
Easy to access from Earth orbit with many current launch vehicles. Staging point for both lunar surface and deep space destinations.

**SCIENCE**  
Favorable vantage point for Earth, sun and deep space observations.

**ENVIRONMENT**  
Deep space environment useful for radiation testing and experiments in preparation for missions to the lunar surface and Mars.

**COMMUNICATIONS**  
Provides continuous view of Earth and communication relay for lunar farside.

**SURFACE OPERATIONS**  
Supports surface telerobotics, including lunar farside. Provides a staging point for planetary sample return missions.
Lunar Science by 2024

**Polar Landers and Rovers**
- First direct measurement of polar volatiles, improving understanding of lateral and vertical distribution, physical state, and chemical composition
- Provide geology of the South-Pole Aitken basin, largest impact in the solar system

**Non-Polar Landers and Rovers**
- Explore scientifically valuable terrains not investigated by Apollo, including landing at a lunar swirl and making first surface magnetic measurement
- Using PI-led instruments to generate Discovery-class science, like establishing a geophysical network and visiting a lunar volcanic region to understand volcanic evolution

**Orbital Data**
- Deploy multiple CubeSats with Artemis 1
- Potential to acquire new scientifically valuable datasets through CubeSats delivered by CLPS providers or comm/relay spacecraft
- Global mineral mapping, including resource identification, global elemental maps, and improved volatile mapping

**In-Situ Resource Initial Research**
- Answering questions on composition and ability to use lunar ice for sustainment and fuel
American Strategic Presence on the Moon –
High solar illumination areas within 2 degrees (<50 km) of the lunar south pole.

Four highly illuminated areas shown above:
1. De Gerlache Rim,
2. Shackleton Rim
3. Shackleton – De Gerlache Ridge
4. Plateau near Shackleton

High Priorities for Sustained Surface Activities

- **Long duration access to sunlight**: A confirmed resource providing power and minimal temperature variations
- **Surface roughness and slope**: Finding the safest locations for multiple landing systems, robotic and astronaut mobility
- **Direct to Earth communication**: Repeatable Earth line-of-sight communication for mission support
- **Permanently Shadowed Regions and Volatiles**: Learning to find and access water ice and other resources for sustainability
Artemis Phase 2: Building Capabilities for Mars Missions

Reusable human lander elements refueled

Artemis 5

Artemis 6

Artemis 7

Artemis Support Mission
Lunar surface asset deployment for longer surface expeditions

CLPS opportunities

SUSTAINABLE LUNAR ORBIT STAGING CAPABILITY AND SURFACE EXPLORATION

MULTIPLE SCIENCE AND CARGO PAYLOADS

INTERNATIONAL PARTNERSHIP OPPORTUNITIES

TECHNOLOGY AND OPERATIONS DEMONSTRATIONS FOR MARS

2025

2029
Science After 2024
Human and Robotic Missions Provide Unique Science Opportunities

On Gateway
- Deep space testing of Mars-forward systems
- Hosts groundbreaking science for space weather forecasting, full-disc Earth observation, astrophysics, heliophysics, lunar and planetary science
- Mars transit testbed for reducing risk to humans

Surface Exploration
- Understanding how to use in-situ resources for fuel and life
- Revolutionizing the understanding of the origin and evolution of the Moon and inner solar system by conducting geophysical measurements and returning carefully selected samples to Earth
- Studying lunar impact craters to understand physics of the most prevalent geologic process in the solar system, impact cratering
- Setting up complex surface instrumentation for astrophysics, heliophysics and Earth observation
- Informing and supporting sustained human presence through partial gravity research in physical and life sciences, from combustion to plant growth

Surface Telerobotics to Provide Constant Science
- Sending rovers into areas too difficult for humans to explore; rovers can be teleoperated from Earth to maximize the scientific return
Human Exploration Strategy

QUESTIONS?